Water Purification Using Plasma Micro-Discharge Towards Development of a Hybrid Water Treatment System

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Introduction

Water scarcity has become a growing problem in the modern era. In the 1900s, 0.24 billion people went without clean water. However, this number has increased to 3.8 billion without access to clean water in the 2000s [7]. This increase is caused by an increase in the global population, which has increased the need for water in agriculture as well, and draughts in various regions throughout the world [7]. Modern solutions to this scarcity including, chlorination, desalination, and filtration have been studied and used extensively but more is needed to solve this problem [3]. A new solution, water purification through plasma discharge has been proposed and is what this project will focus on.

Plasma

Plasma is an electrical phenomenon. It is the state of matter in which electrons are stripped off of atoms and behave erratically with the ions, like a fluid, since it flows directionally, and partially like a conductor of electricity. Many early experiments in plasma described this state of matter as, "electrically conductive gas" before a more general theory of plasma was developed. This water purification experiment involves small electrical discharges between a tungsten needle and the water solution in close proximity. The tungsten needle is fed a high voltage signal, with low current, whose waveform can be analyzed, and some generalization can be made about the properties of the plasma discharges through the water. The voltage produces a powerful electric field near the tip of the needle in reference to the water. The electric field strength then overcomes the permittivity of air, like water pouring over a dam, and electrical discharges of different power and frequency can be observed [5]. For this project, experiments will be conducted using both pulsed and stable corona discharges, as seen below, to determine which regime best suits water purification though plasma discharge

Corona Discharge

Figure 1: Stable discharge regime.

Figure 2: Pulse discharge regime.

Abstract

The greatest challenge facing our world, today, is a lack of clean water. In 2013, the United Nations reported that 783 million people lacked access to clean water while approximately 2.5 billion did not have adequate sanitation, causing six to eight million deaths annually. Additionally, nearly 90% of wastewater is not treated before reentering natural bodies of water, destroying entire ecosystems, and populations that use the contaminated water [1]. This project concerns the use of micro-plasma discharge to purify water efficiently. Plasma has a number of newly emerging uses, including water treatment processes, which have multiple benefits that include a lack of toxic byproducts. [2, 3]. Researchers at NASA's Glenn Research Center in Cleveland, Ohio have developed a plasma discharge method of water reclamation for use on spacecrafts, but the technology has diverse applications [4]. Such developments, paired with new energy production technologies, will allow plasma based water purification systems to address the global demands for improved sanitation and clean water [4]. This project begins with construction of an apparatus that will produce a corona discharge, a type of plasma discharge with high voltage and low current, by creating a high electric potential between a conductive needle and a grounded electrode submerged in water. The discharge propagated across the intermediate region causes electroporation in bacteria, preventing them from reproducing; UV radiation, which kills other organisms; and Ozonation, which chemically cleanses the water [3]. Water contamination data will be collected to optimize the effectiveness and energy efficiency of the system. Both electrode distance between the needle and grounded plane, and use of a dispersive medium positioned between the two, will be considered. The findings will allow future researchers to begin with an optimized system, providing a foundation for the design of improved water treatment systems.

The Purification Process

To achieve water purification, a small brushless DC motor, which feeds a micro-pump, will pump black or grey water from a holding tank though a small trough. TheThe treatment process begins in one beaker, which contains unpurified black water. This water is then transferred, using a DC electric pump to valve where it is split in two directions. One leads back to the initial holding tank, in order to prevent pressure build up on the pump, while the other leads to a tank where the water will be treated. Once in the tank, the water is exposed to a corona discharge, between an electrode suspended above it and a base electrode, which comprises the floor of the container. This process is used to purify the water, and the treated water is pumped out of the tank and into a second beaker which will keep the treated water separated from the original black water.

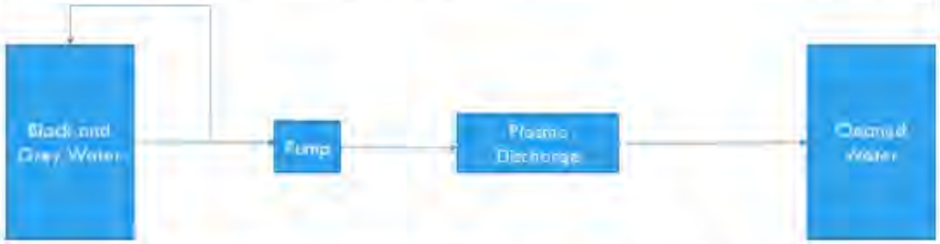

Figure 3: The water purification process. Water flows from left to right as describes above.

Figure 4: Tank used to contain water during treatment.

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Purification

When water passes through the discharge, an electrical field and current passes through the water to a ground. This causes a series of reactions purifying the water. First. The electric field present destroys bacteria and virus DNA and RNA, preventing the organism from reproducing. Additionally, the presence of an electrical current causes the dissociation of ions within the water. This produces free radicals which react with other chemicals neutralizing toxic chemical such as chlorine and fluorine. This effectiveness of this process is analyzed through the use of a Total Dissolved Solids meter. A TDS meter is to measure the ionized solid content of the water, as a rough measure of water purity. The TDS meter works by analyzing electrical conductivity of the water solution, and increased conductivity will be a sign of higher dissolved solid and mineral content in the water solution[6]. Results will indicate how the plasma discharges is affecting the water solution.

Conclusion

Through preliminary experimentation, the demands of the each regime were found to be as follows. To produce a stable continuous discharge, the regime requires a minimum of 5 kV voltage and 100 μA while not exceeding 7 kV and 200 μA. To produce a pulsed discharge, the regime requires a minimum of 7kV and 200 μA. Our high voltage generator does not produce enough power to mover into a thermal discharge which is the next regime above pulsed discharge. Thus, both regimes do exist and further experimentation will be conducted to determine which regime optimizes water purification.

References

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